

DEVELOPMENT OF ACC FOR VEHICLE WITH MAUAL TRANSMISSION

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SUMMARY

ACC system has been developed and carries out the spread of various vehicles. This paper explains MT vehicle equipped with outline of ACC along with the investigation and the results of driving tests. Especially the mental workload reduction was evaluated. In addition, characteristic problems and its solutions were introduced in this paper.

INTRODUCTION

In recent years, ACC is put in practical use and has been amounted on various vehicles. Conventionally, the system was applied to the vehicles which are with AT (automatic-transmission) or CVT. For the needs expansion of ACC, we successfully developed one for a MT (manual transmission). Because of the feature of MT operated to the range of a gear position chosen by the driver, the driver is required as making a shift change at an appropriate moment, which is not required on an AT vehicles.

As another significant feature of MT vehicles, it can transmit engine torque to tires directly from the clutch without a torque converter. It enables high response control which is not in AT vehicles. On the other hand, it became the subject to realize a smooth vehicle behavior. Therefore, we developed ACC for MT vehicles which has both a high response and smooth operation by new control method.

This paper describes the outline of the validity of ACC for MT vehicles and the technology which realized the smooth vehicle behavior.

SYSTEM FEATURES

System Outline

This ACC system uses a laser sensor for the headway distance measurement and electronically controlled vacuum brake booster for deceleration. And they are on the MT vehicles. The system configuration is shown in Fig. 1.

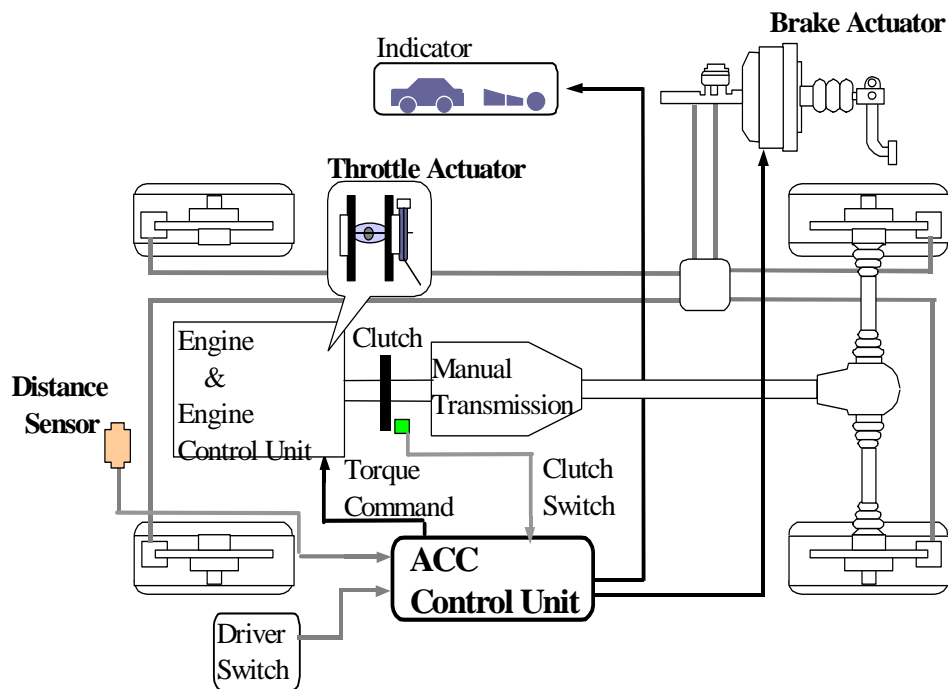


Figure1 ACC System Configuration

ACC control unit outputs engine torque command value to the engine control unit. Based on this command, the engine control unit controls throttle opening. As for braking, the vehicle uses engine brake and hydraulic pressure brake by electronically controlled vacuum brake booster together in the same way as ACC for AT vehicles.

System Feature

One of the big differences between MT and AT is whether the driver needs to shift the gear position. Since, in MT vehicles, ACC can be used only in the speed range of the gear position which the driver chose, the control range of ACC is restricted for each shift position compared to AT vehicles. And ACC control will be canceled at the time when clutch disconnection is detected in a shift change by clutch SW.

Another great difference is transmitting engine torque which is transferred to tires directly through a clutch without a torque converter. Because of the direct transfer of engine torque as driving force, high response can be realized. In contrast, it generates the backlash of the drivetrain and causes the disturbance of a vehicle behavior.

USEFULNESS EVALUATION OF ACC WITH MT

Frequency of MT Gear Shift

As for the MT vehicles, a driver itself must operate a shift if necessary, and ACC automatically canceled at that time. If

shift operation is demanded from driver at many times, the re-set of ACC is very troublesome by driving under the state of ACC set.

Table 1.
Gear Shift Frequency

<u>Average of shift down (6th to 5th) frequency on the highway</u> 5.94 Times / 100km It is counted the shift down frequency between 40 km/h and 100 km/h.

We investigated the frequency of gear change in ACC operation speed range in vehicle without ACC. Analyzing this data, it turns out that the gear position change was hardly operated in ACC operation speed range. If the driver use ACC on MT vehicle, the physical workload is obviously decreased. It can be said that ACC on MT vehicle is also useful enough because gear shift frequency of MT vehicle with ACC can be supposed almost equal to vehicle without ACC. Next, we point out the character of ACC on MT vehicles with a viewpoint of mental workload.

MENTAL WORKLOAD

Outline

When using ACC with MT, we feel the driving fatigue is lower than the case of not using ACC. In this section, we will discuss the reduction effect of mental workload based on the results of heart rate, flicker value and subjective evaluation.

Condition of Evaluation

This evaluation was performed on TOMEI automobile highway under the following 4 patterns.

Evaluation Patterns

- 1) CVT vehicle, not using ACC
- 2) CVT vehicle, using ACC
- 3) MT vehicle, not using ACC
- 4) MT vehicle, using ACC

Number of Subjects

2 divers (The drivers A and B are familiar to this system)

Driving Conditions

Driving for 80minutes continuously between 70 and 100 km/h.

Obtained Data

- 1) Heart rate (While driving)
- 2) Flicker test (Before driving and after)
- 3) Subjective evaluation (After driving)

Test Vehicle Specs

- 1) PRIMERA 2.0L, CVT with ACC (This car is already sold in Europe and Japan)
- 2) PRIMERA 2.0L, 6 speed MT with ACC (This car is already sold in Europe)



NISSAN PRIMERA

Analysis Based on Heart Rate Data

This paragraph presents the results of mental workload measured using cardiograph data. In the analysis, the interval and its variance in the heart rate data is examined to determine an index to show driver's mental condition as to whether the driver is tense or relaxed, etc.

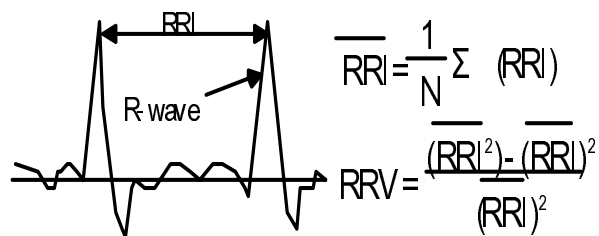


Figure2. Heart rate Wave

Fig. 2 shows the calculation formula to identify the correlation between the waveform of heart rate and fluctuation of heart rate interval. Pulse wave of heart rate waveform is referred to as R wave and its interval is referred to as RRI (R-R interval). RRI is an inverse of cardiograph. Accordingly, it is known that when RRI decreases, the subject is tense. RRV (R-R variance) is normalized fraction of RRI. When the driver's tension increases, RRV decreases and it increases when the driver is more relaxed. Fig. 3 and Fig. 4 show subject A's average value of RRI and RRV for every 20 min while long time driving. Subject B showed the identical result. When comparing the results of the four conditions (with and without the System, CVT and MT) in the graphic chart, there is no clear deference of four conditions. Because the results of subject A shows that he is fully relaxed in all conditions. Using paragraph can not find differences. That is, ACC of MT does not increase mental workload and its level is as much as the case of no using ACC system.

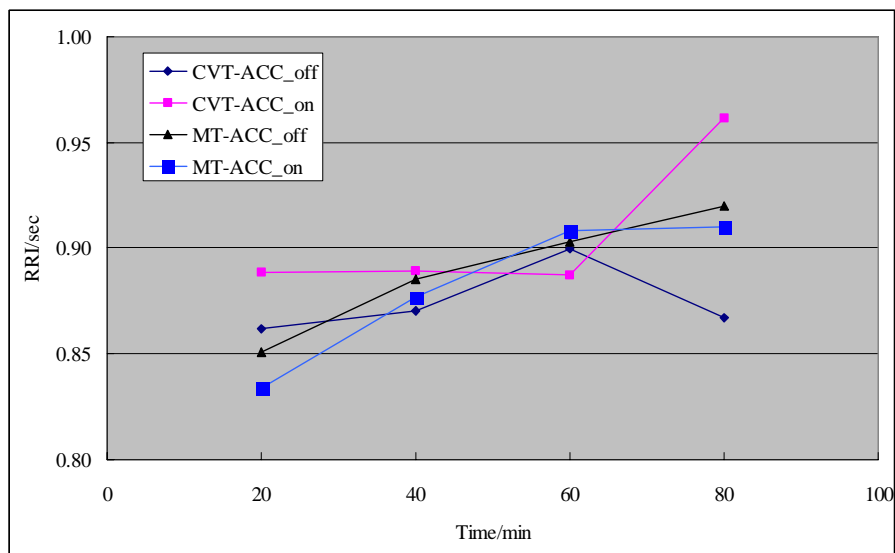


Figure3. RRI (subject A)

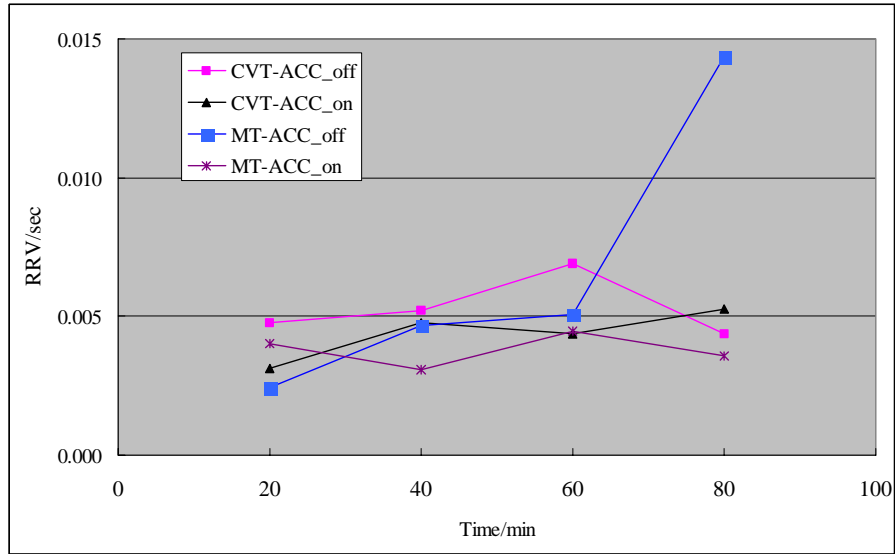


Figure4. RRV(subject A)

Analysis Using Flicker Tester

In the experiment we performed, we measured the workload using flicker tester which was used in the traditional measurement. When a person sees a flashing light, it is seen by the person as a continuous light when the flashing speed reaches a certain speed. The frequency of the light at that point is referred to as flicker value which is used as one of the criteria to measure the fatigue of a person. When flicker value lowers, a person is deemed to be more tired. The measurement was performed under the condition of long time driving. Flicker measurement was performed before and immediately after the experiment is completed. In Fig. 5, the result of flicker measurement of the two subjects A and B are shown. Vertical axis shows the flicker value and horizontal axis indicates subjects A and B when the system is on and off. White and black circles on the graphic chart show flicker value before and after the experiment, respectively. When comparing the result of the experiment with and without the System, it is found in both subjects A and B that the rate of decrease of flicker value after the experiment shows a greater value when the system is not used. Therefore, it is estimated that there is a greater fatigue when the system is not used. And in the case of MT, the difference between ACC used and not used is greater than CVT's. So we estimate adopting ACC to MT vehicle is more effective than CVT vehicles.

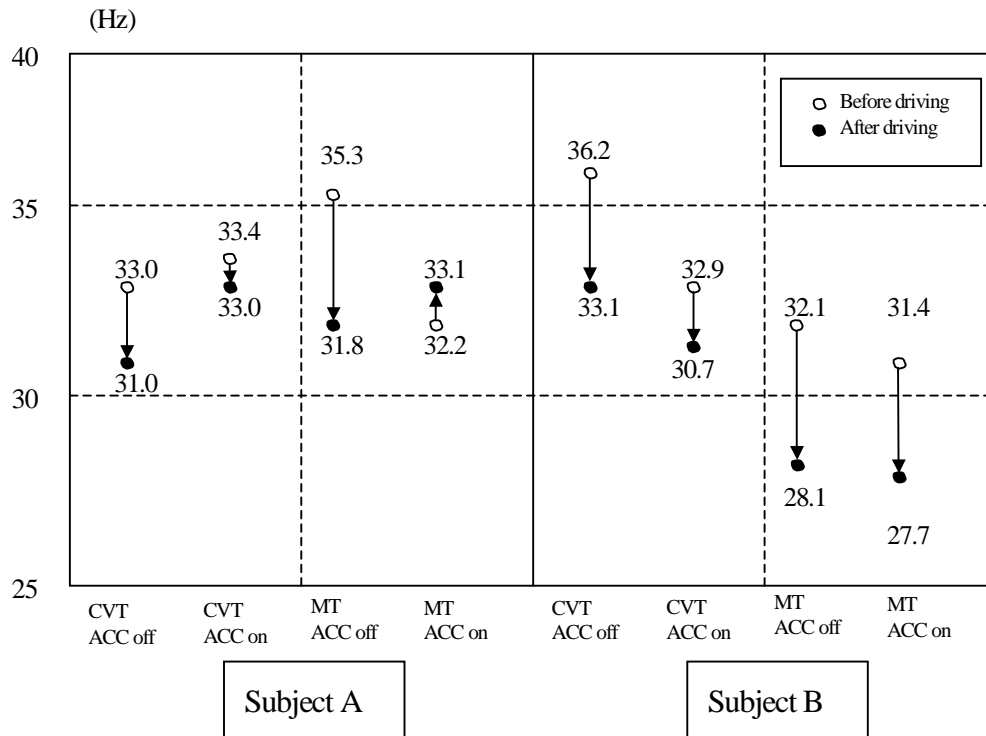


Figure5. Results of Flicker value

Analysis of Subjective Evaluation

We have discussed so far the effect of reduction of mental workload identified through biological measurement. This section analyzes the results of the subjective evaluation data. We asked the subjects four questions ("do you feel neural fatigue?", "do you feel that there are many physical operations?", "do you feel any pressure for time?" and "do you get irritated?") and the classified the response with reference to NASA-TLX method, which is often used in measuring workload. The evaluation was performed immediately after the long distance driving. Fig. 6 shows averages of two subjects for each of evaluated items. Bars in gray indicate the experiment results when the System was not used and black bars indicate the experiment results with the System. The workload was found higher for all the evaluated items when the system was not used. The improvement of MT vehicle is bigger than CVT vehicles.

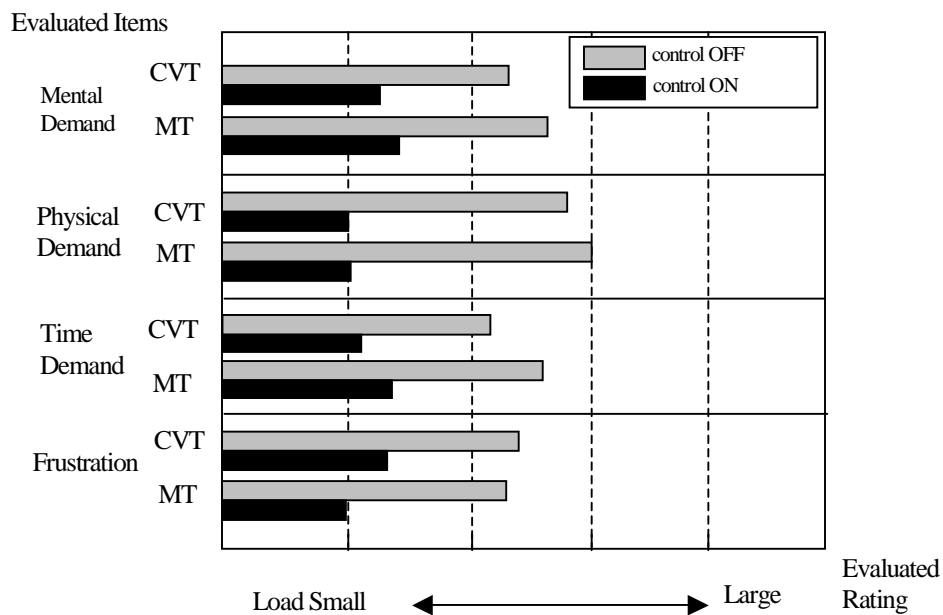


Figure6. Subjective rating for driving loads

ADOPTING PECULIER TO MT VEHICLE

ACC was very useful system at MT vehicle, however some peculiar troubles arose. Here we show characteristic problems happened by MT vehicles.

Outline of Acceleration Shock

Since acceleration shock and so on is conveyed to the driver, and it feels an uncomfortable for MT vehicles. In AT and CVT vehicles, the acceleration shock is not occurred because the torque converter absorbs the mechanical backlash. Correcting ACC control logic, in order to check and solve the problem. It can transmit engine torque to tires directly from the clutch without a torque converter.

Driver feels uncomfortable shock in some driving conditions. The acceleration shock is generated in following 2 situations.

- (1) After forward vehicle decelerate, it accelerates again.
- (2) Driver operates resume function

Acceleration shock is shown in Fig.7.

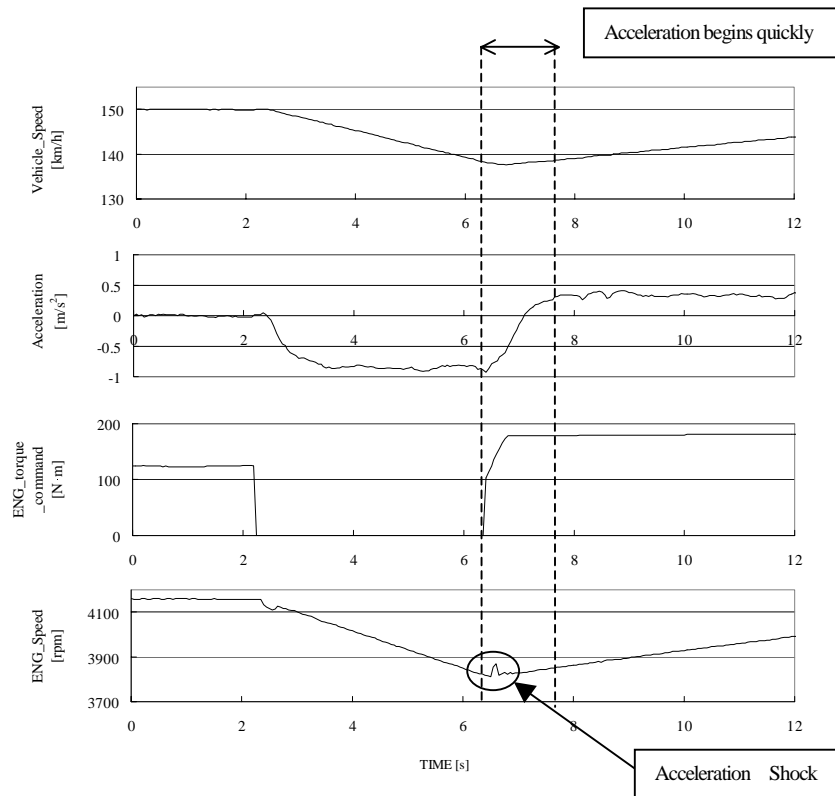


Figure7. Acceleration shock data

It turns out that engine speed changes when an acceleration shock occurs by evaluation data. This can be conjectured to mean that the drivetrain backlash caused the acceleration shock when the engine torque rises rapidly. The shock is marked 2 in subjective evaluation. By which subjective rating is defined by evaluation, 10 is the best level that can not be felt. 4 is NG level. So 2 shows the level of the shock is big problem.

Adding Simple Control Logic

First, simple restriction of engine torque command was set up, and the confirmation of the effect was done. When the rate of engine torque rising is limited lower, the backlash becomes smooth. Then there is few acceleration shock. The result is shown in Fig. 8.

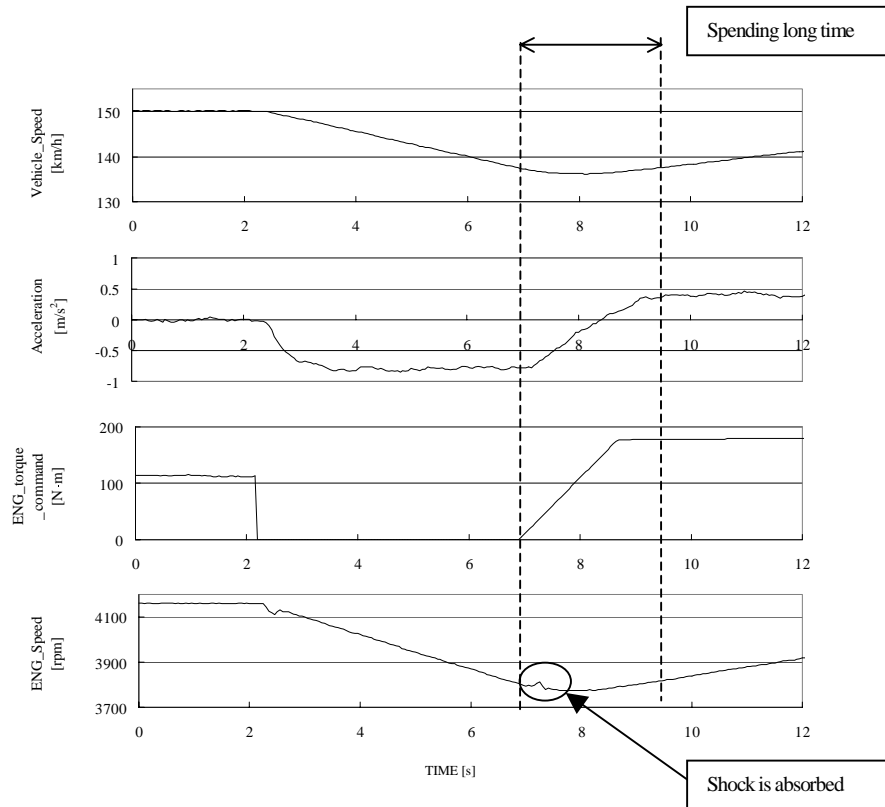


Figure8. Simple restriction of engine torque command

From the result, jump of engine speed becomes small and it could be checked that a shock has been decreased to it. Similarly, it is improved to subjective rate. It paid attention to subjective rate changing by the difference in the rise slope of engine torque, and the correlation was analyzed. This is shown in Fig. 9.

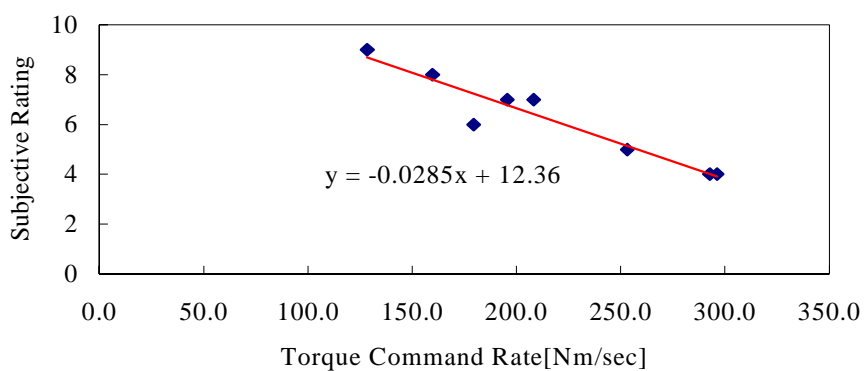


Figure9. Correlation of subjective rate and engine torque rising

Fig. 9 shows the relation between rise slope value of engine torque command and subjective evaluation value. As the above-mentioned guesses, if the rise slope value of engine torque command will be small, the level of an acceleration shock becomes small and subjective rating value are also high. But if a rise slope of engine torque is suppressed too much, vehicle

acceleration becomes poor and it become impossible in order that it might fill the performance of ACC system.

An acceleration shock could be made small by giving a limit to an engine torque order. On the other hand, vehicle acceleration is NG level because the engine torque occurs late.

Adding New Control Logic

Introducing new control logic to coexist acceleration shock relief and poor acceleration improvement, and check the effect. The new logic limits the rise rate of engine torque command until drivetrain backlash happen, and after that the restriction is removed.

New Logic Feature

New logic restricts an engine torque command value as simple control logic till drivetrain backlash happen. The logic is shown in Fig. 10.

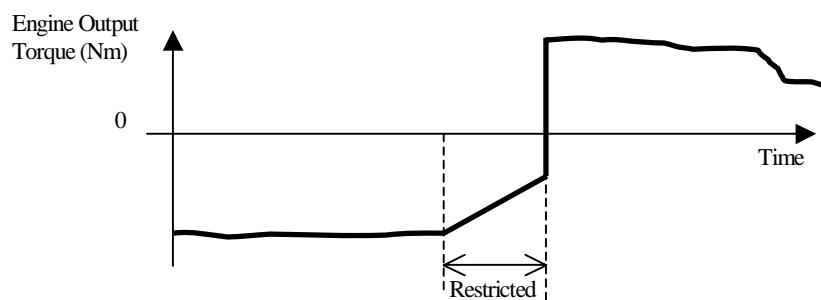


Figure10. New logic concept

Evaluation Result

The acceleration shock was solved by the new control logic without sacrificing vehicle acceleration performance by ACC operation. The result is shown in Fig. 11

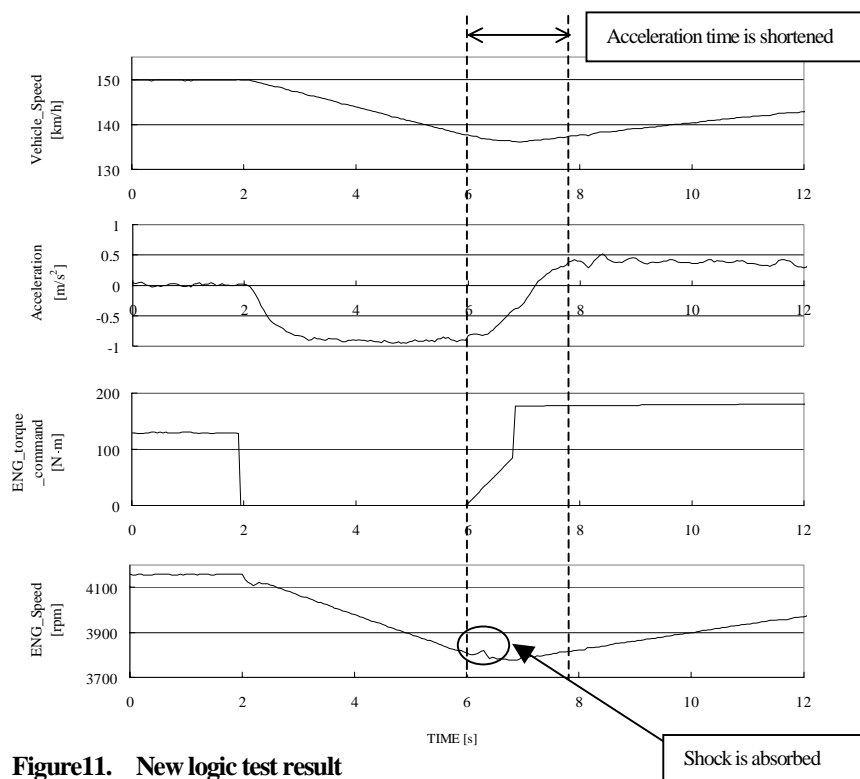


Figure11. New logic test result

CONCLUSION

The feature and the theme in the case of applying ACC to MT vehicles are summarized below.

1) System cancel which is caused by MT gear change never spoils the convenience of ACC because MT operation frequency in ACC set speed range is rare.

2) When ACC was mounted to MT, it confirmed that mental workloads has been decreased.

As a result, it has become clear that ACC is a very effective system for MT vehicles as well. 3) Although the particular acceleration shock caused by drivetrain backlash, it is possible to solve it by modifying the engine torque command characteristic. With this method, coexistence of rapid response and smooth vehicle behavior are realized.

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